

Implementation of conceptual validation of product mock ups with augmented reality

Implementación de la validación conceptual de modelo blando con realidad aumentada

Gilberto Osorio-Gómez
gosoriog@eafit.edu.co

Ricardo Mejía-Gutiérrez
rmejiag@eafit.edu.co

David Ríos-Zapata
drioszap@eafit.edu.co

*Grupo de Investigación
en Ingeniería de Diseño (GRID)
Universidad EAFIT, Medellín (Colombia)*

.....
Fecha de recepción: Junio 2 de 2012

Fecha de aceptación: Julio 31 de 2012

Keywords

Augmented reality; electrical mobility; product design engineering; computer tools; concept validation.

Palabras clave

Realidad aumentada; movilidad eléctrica; ingeniería de diseño de producto; herramientas informáticas; validación de conceptos.

Abstract

The implementation of computational aids in product design is a demand in the design processes on century XXI, that because they allow an increase in quality and creativity of the deliverables of a design process. But this implementation should be guided to an academic process, where technologies methodologies work along. This article presents the results of an implementation of virtual reality techniques to validate and increased product design courses within the undergraduate electrical mobility in Product Design Engineering at that university.

Resumen

La implementación de ayudas informáticas en el diseño de productos es prácticamente una demanda en el diseño del siglo XXI, ya que su uso permite un aumento de la calidad y la creatividad de los entregables de un proceso de diseño. Pero esta implementación debe estar guiada por un proceso académico, en el cual se implementen tecnologías y metodologías de trabajo. El presente artículo muestra los resultados de una implementación de técnicas de realidad virtual y aumentada para validar el diseño de productos en cursos de movilidad eléctrica dentro del pregrado en Ingeniería de Diseño de Producto en la Universidad EAFIT.

I. Introduction

Computer tools are used to facilitate the human tasks, therefore, also to facilitate the product design processes by offering designers to spend more time in creativity rather than detail (Robertson & Radcliffe, 2009), moreover, the implementation of different computer tools in design processes have increased the success rate of the new up to 60% (Valle & Vazquez-Bustelo, 2009).

Considering all the impact that the implementation of computer tools had over design processes, there is important to identify the different computer tools that can be implemented on each stage on a product design.

In this connection, computer tools can be described by their usage in product life cycle (Product life cycle: Need, design, manufacture, distribution, usage and disposal (Kusiak, 1993)) in two different classes. Those that can be used through all design stages, that are called collaborative-work support tools and those that are used on specific design stages, that are called functional tools (Osorio-Gómez, Mejía-Gutiérrez & Ríos-Zapata, 2012).

Collaborative-work support tools are used to empower collaborative and distributed work based on concurrent engineering principles (principles described on Concurrent engineering fundamentals- Integrated product and process organization [Prasad 1996]), and three types can be described: communication tools, project management tools and information management tools (Osorio-Gómez et al., 2012).

Functional tools have the characteristic to be used to solve specific tasks inside the product design process, and are divided into four categories: analysis tools, modeling tools, representation tools and simulation tools (Osorio-Gómez et al., 2012).

This article presents the implementation of functional computer tools into the validation of product mock-ups by the implementation of augmented and virtual reality simulation techniques on product design projects in electric mobility taught at Universidad EAFIT in the undergraduate program of Product Design Engineering.

II. Methods and materials

A) Context

In Product design engineering, several design methodologies are wrapped on electrical mobility courses, including those that are by far the most known in education and industry (Tomiya, Gu, Jin, Lutters, Kind & Kimura, 2009), like Pahl and Beitz that can be summarized in four steps: Planning and clarification of the task, conceptual design, embodiment design and detail design (Pahl, Beitz, Feldhusen & Gote, 2007); others important methodologies that made part of PDE methodologies are Baxter (which is described in six steps: business opportunity, design specifications, concept

design, embodiment design, detail design and design for manufacture (Baxter, 1995) and Ulrich and Eppinger, that has six steps, one of them, focused in testing and validations of products (product planning, concept development, system level design, detail design, testing and refinement and production ramp-up (Ulrich & Eppinger, 2004).

Based on these methodologies, a design methodology was adapted for electrical mobility courses. This methodology can be watched on Figure 1. It important to recall that electrical mobility course is a year course that is composed by different two courses, Project 7 and Project 8.

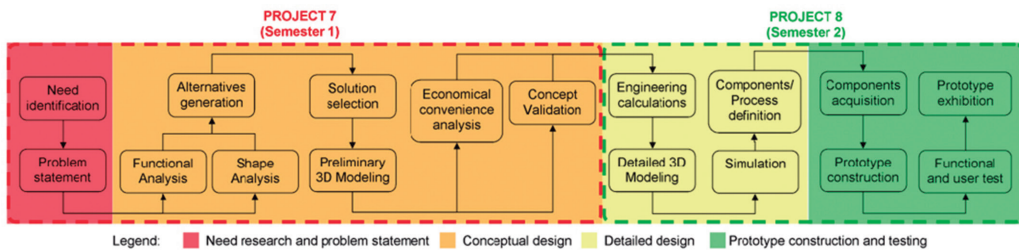


Figure 1. Adopted design methodology (Osorio-Gómez, Mejía-Gutiérrez & Sierra, 2011)

At the end of Project 7, students must deliver a mock-up of their designed electrical product; these mock up is then validated through use of virtual and augmented reality techniques.

Validation tests during the product design and development process are conducted at different stages and guarantee the functionality and acceptance of the proposed solutions in advance of its industrialization process reducing time and costs and improving the final quality of the result. Such validation is carried out through the implementation of different kind of prototypes, such as physical prototypes, virtual prototypes or abstract prototypes (Horvath, 2011). In the current design engineering practice, at both academic and industrial level, prototypes are usually created as physical or virtual prototypes; and each one includes a different level of information related to the design parameters of the solution. Virtual prototypes are often adopted to realize the geometry and the structural composition of the product and they are used in simulation or visualization tasks, but the human-product interaction is restricted to the computer interface. In the other hand, physical prototypes are implemented at different stages of the design process according to their level of elaboration, but they are a little flexible and their quality and functionality is time and cost dependent. Simple and non-functional physical prototypes are useful for preliminary validations in the initial phases of the process and detailed and functional physical prototypes are useful to evaluate functionality, aesthetic aspects (such as shape, textures and colours) and physical aspects (such as weight) at later stages of design.

Anyway, the virtual reality (VR) application with its immersive environments and intuitive interfaces allows a better validation of the products and the experience gets better when the number of involved human senses increases. This is directly related to the cost of hardware and software and neither real components nor environments are considered.

At this point, the augmented reality (AR) application is useful to integrate physical and virtual prototypes allowing their interaction and yielding information in real time for design validation, at lower costs than VR and in a much simpler manner. A good description of different uses of AR at different stages of the product development process could be observed at (Uva, Fiorentino & Monno, 2011) where the authors present different technical considerations according to the product development scenarios and applications. Here it is worth noticing the level of required knowledge related to computer graphics and animation.

Therefore, considering that Product Design Engineering students are not related to this kind of visualization and representation tools and their programming skills are not well developed during their academic background, at the last semesters of the curriculum during the one-year lasting project they are introduced to a basic AR experience in order to allow them evaluating their proposed solutions after the conceptual solution definition, integrating the virtual model of the proposed product along with a physical non-functional mock up.

B) Augmented reality implementation

Across the Project 7 course, students must do a preliminary 3D model of the electric product they are designing. Parallel to the construction of a 1:1 scale mock-up, they must start with pre-work in order to validate their model using virtual and augmented reality. These are the steps that must be followed in the pre-work:

- » Develop the 3D model of their product.
- » Identify in their model the places where augmented reality markers are going to be located. For so, students must consider the critical views on their model, those where more detail is needed.
- » To each critical spot identified, assign a coordinate system. To each system must be associated the relative translations and rotations from global coordinate system.

Defined the places where augmented reality markers are located, then a multi-marker set up must be build. Each marker must follow the structure shown on Figure 2:

- » Line 1: Marker number
- » Line 2: Path of the marker
- » Line 3: Marker width
- » Line 4: Offset on X-Y of marker coordinate system
- » Line 5-7: Rotational and translational matrix of marker coordinate system against global coordinate system.

```
#marker 1
Data/patterns/multi/g1.patt
100
0.0 0.0
1      0      0      0
0      0      -1     -224
0      1      0      476
```

Figure 2. Multi-marker structure

Finally, the structure of rotational and translational matrix can be appreciated on Equation 1, where R is related to rotation and T to translation on the three axes. Equation 2 shows the equivalent rotations matrix for the three axes.

$$\begin{bmatrix} R_{11} & R_{12} & R_{13} \\ R_{21} & R_{22} & R_{23} \\ R_{31} & R_{32} & R_{33} \end{bmatrix} \begin{bmatrix} T_x \\ T_y \\ T_z \end{bmatrix} \quad \text{Equation 1}$$

$$Rot(z) = \begin{bmatrix} \cos\theta & -\sin\theta & 0 \\ \sin\theta & \cos\theta & 0 \\ 0 & 0 & 1 \end{bmatrix}, Rot(y) = \begin{bmatrix} \sin\theta & 0 & \cos\theta \\ 0 & 1 & 0 \\ \cos\theta & 0 & -\sin\theta \end{bmatrix}, Rot(x) = \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos\theta & -\sin\theta \\ 0 & \sin\theta & \cos\theta \end{bmatrix} \quad \text{Equation 2}$$

The pre-work of the validation finish with the construction of the mock-up and the location of the markers on the product. An example of a markers location on mock up can be watched on Figure 3.



Figure 3. Mock-up set up with augmented reality markers (Photo: Project 7 20112)

III. Results

A) Project 7 and augmented reality validations

At the end of the Project 7, students must present their mock up set up for virtual and augmented reality validation. This is done on a public showcase made at the last week of semester. Figure 4 shows mock ups presented on the showcase.



Figure 4. Mock ups with augmented reality markers presented on final showcase (Photo: Project 7 2011-2, 2012-1)

.....

In order to facilitate the validation it was developed a product (VR/AR glasses) that allows creating an immersive environment that supports the validation of the products through virtual and augmented reality. This product was built in the research group of product design (GRID) of Universidad EAFIT. On Figure 5 it can be appreciated the experience during the showcase, which included teachers, judges, students and parents as well.

.....



Figure 5. Immersive environment with mock ups by the use of VR/AR developed glasses (Photo: Project 7 2011-2, 2012-1)

.....

Finally Figure 6 shows how the virtual environment fit the real environment by the use of the VR/AR glasses during the final show case.

.....



Figure 6. Immersive environments on Project 7 (Photo: Top: Project 72012-1. Bottom: Project 2011-2)

B. Project 8 and results of augmented reality validation

On Figure 6 it can be watched on concept that was previously validated by the use of virtual and augmented reality, finally on Figure 7 the final result of the electrical mobility project can be watched. Then it can be watched the final result of the project shown on Figure 3 and bottom of Figure 7.

.....



Figure 7. Project 8 showcase

Discussion

.....

The implementation of augmented and virtual reality techniques had improved the experience of product design students in terms of validation of aesthetics, proportions, functional and ergonomics aspects of their products. Even if these VR/AR validations had started on 2011, they had already shown high impact in how the Product Design Engineer Students design, and these tools had begun to break the paradigm.

Most of the influence is related that students can validate different design alternatives without investing time and money by building functional mock ups. On academics, this has represented a positive change, because students are more confident to design products in higher level of complexity, this, because the VR/AR validation acts as a milestone in the design of the project, and many of the trials done in the immersive environment result as an important feedback within the detail design stage, which is the first part of Project 8, when the final functional model must be designed and build.

Moreover, since Product Design Engineering Students have already experience in working with virtual or augmented reality, they feel free to work with this technologies not only as mandatory activity on Project 7, but some students are already implementing these simulations in their final undergraduate projects and subjects in postgraduate courses.

Finally, the implementation of these simulations had the higher impact in how ergonomics is being validated; even if Computer Aided Drawing tools had ergonomics modules, the validation done in the immersive environments during the final showcase had become one of the most significant source of feedback taken by the students for being considered on next design stages. ^{S&T}

Referencias bibliográficas

- Baxter, M. (1995). *Product design. A practical guide to systematic methods of new product development*. London, UK: Chapman and Hall
- Horvath, I. (2011). Theoretical framework for comprehensive abstract prototyping methodology. En *Proceedings of the 18th International Conference on Engineering Design (ICED11)*, Vol. 2 (pp.108-119). Glasgow, UK: The Design Society
- Kusiak, A. (1993). *Concurrent engineering: automation, tools, and techniques*. New York, NY: Wiley-Interscience
- Osorio-Gómez, G., Mejía-Gutiérrez R., Sierra, L.F. (2011). An academic design methodology for electrical mobility products –from necessity to functional prototype–. In A. Kovacevic et ál. (Eds.), *Design education for creativity and business innovation*, (pp.589-595). ISBN: 978-1-904670-33-9. London, UK: The Design Society / Institution of Engineering Designers
- Osorio-Gómez, G., Mejía-Gutiérrez, R., & Ríos-Zapata, D. (2012). A computer tools classification based on collaborative engineering environments and its value on education. In *Proceedings of INTED2012 Conference*. 5th-7th March 2012. Valencia, Spain: IATED
- Pahl, G., Beitz, W., Feldhusen, J., & Gote, H. (2007). *Engineering design: A systematic approach*. London, UK: Springer Verlag
- Prasad, B. (1996). *Concurrent engineering fundamentals. Integrated product and process organization*. Upper Saddle River, NJ: Prentice Hall
- Robertson, B. & Radcliffe, D. (2009). Impact of CAD tools on creative problem solving in engineering design. *Computer-Aided Design*, 41(3), 136-146
- Tomiyama, T., Gu, P., Jin, Y., Lutters, D., Kind, C., & Kimura, F. (2009). Design methodologies: Industrial and educational applications. *CIRP Annals-Manufacturing Technology*, 58(2), 543-565
- Ulrich, K., & Eppinger, S. (2004). *Product design and development*. Boston, MA: McGraw-Hill / Irwin.
- Uva, A.E., Fiorentino, M. & Monno, G. (2011). Augmented Reality Integration in Product Development. In *Proceedings of the International conference on Innovative Methods in Product Design (IMProVe 2011)*, June 15th – 17th, Venice, Italy (pp. 73-79). Available in http://www.improve2011.it/Full_Paper/211.pdf
- Valle, S. & Vásquez-Bustelo, D. (2009). Concurrent engineering performance: Incremental versus radical innovation. *International Journal of Production Economics*, 119(1), 136-148

Currículum vitae

Gilberto Osorio Gómez

Profesor-Investigador del Departamento de Ingeniería de Diseño de Producto de la Universidad EAFIT y miembro del Grupo de Investigación en Ingeniería de Diseño de Producto (GRID). Coordina cursos de proyectos de movilidad eléctrica. Se graduó como Ingeniero Mecánico de la Universidad Nacional de Colombia – Sede Medellín en 2003 y en el 2009 de Doctor en Investigación en Ingeniería de Sistemas Mecánicos del *Politecnico di Milano* (Italia).

Ricardo Mejía

Profesor-Investigador del Departamento de Ingeniería de Diseño de Producto de la Universidad EAFIT y Director del Grupo de Investigación en Ingeniería de Diseño de Producto (GRID). Se graduó como Ingeniero de Producción de EAFIT, obtuvo su Maestría en Sistemas de Manufactura del Instituto Tecnológico de Monterrey (México) y un Ph.D en Ingeniería Mecánica y Diseño de la *École Centrale de Nantes* (Francia).

David Ríos

Asistente de Investigación en el del Grupo de Investigación en Ingeniería de Diseño de Producto (GRID) de la Universidad EAFIT, donde actualmente adelanta estudios para la obtención de su Maestría en Ingeniería en Herramientas Computacionales en Diseño de Productos. Se graduó en 2009 de Ingeniería Mecánica en la Universidad EAFIT.